

Secure Transmission of Information

Team: VSLQ

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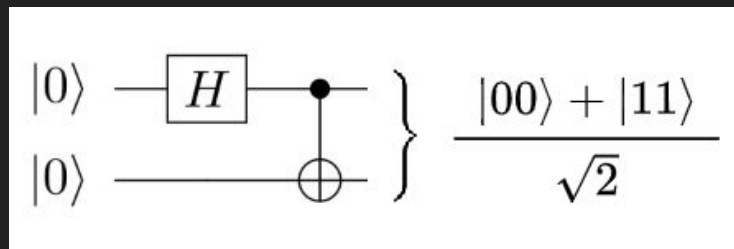
Idea

- Use **Super Dense coding** technique to transmit information encoded in a
 - ◆ Bell state : transmit 2 bits by sending 1 qubit
 - ◆ GHZ state : transmit 3 bits by sending 2 qubits
- Try classical error correction scheme (majority vote) and rectify the error in the output

Bell and GHZ states

The schemes utilize maximally entangled 2-qubit (Bell) and 3-qubit (GHZ) states

Bell State

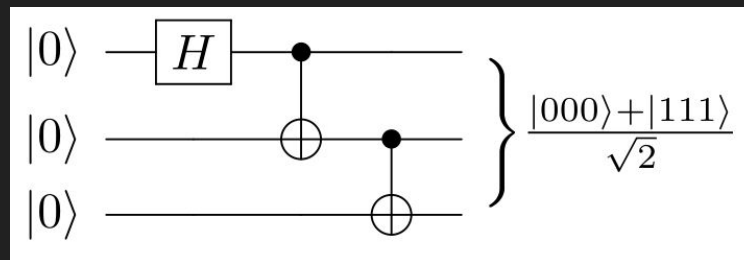


4 different Bell pairs

$$|\phi^{\pm}\rangle = \frac{|00\rangle \pm |11\rangle}{\sqrt{2}}$$

$$|\psi^{\pm}\rangle = \frac{|10\rangle \pm |01\rangle}{\sqrt{2}}$$

GHZ State

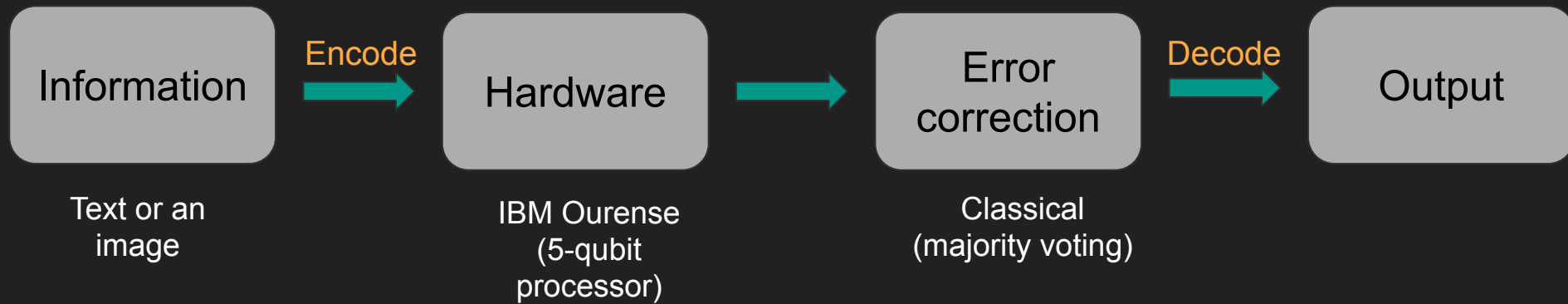


8 different GHZ states

$$|\psi_A^{\pm}\rangle = \frac{|000\rangle \pm |111\rangle}{\sqrt{2}} \quad |\psi_B^{\pm}\rangle = \frac{|100\rangle \pm |011\rangle}{\sqrt{2}}$$

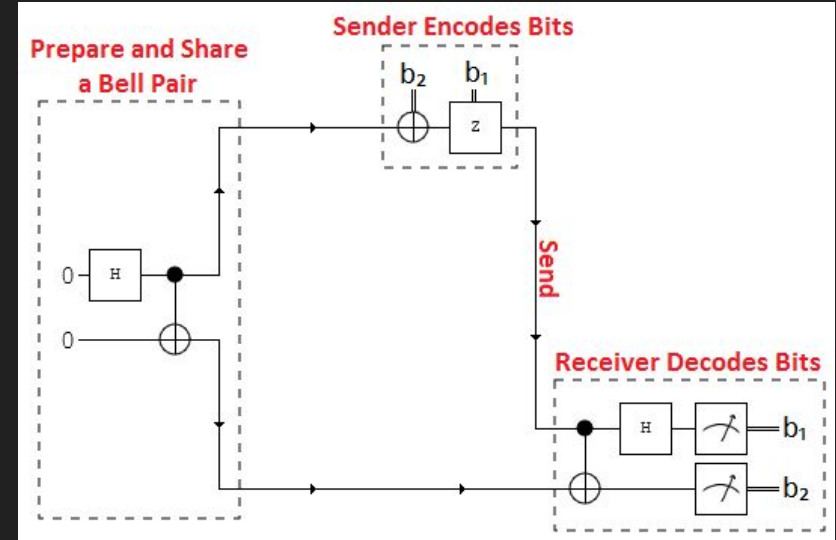
$$|\psi_C^{\pm}\rangle = \frac{|010\rangle \pm |101\rangle}{\sqrt{2}} \quad |\psi_D^{\pm}\rangle = \frac{|001\rangle \pm |110\rangle}{\sqrt{2}}$$

General Method



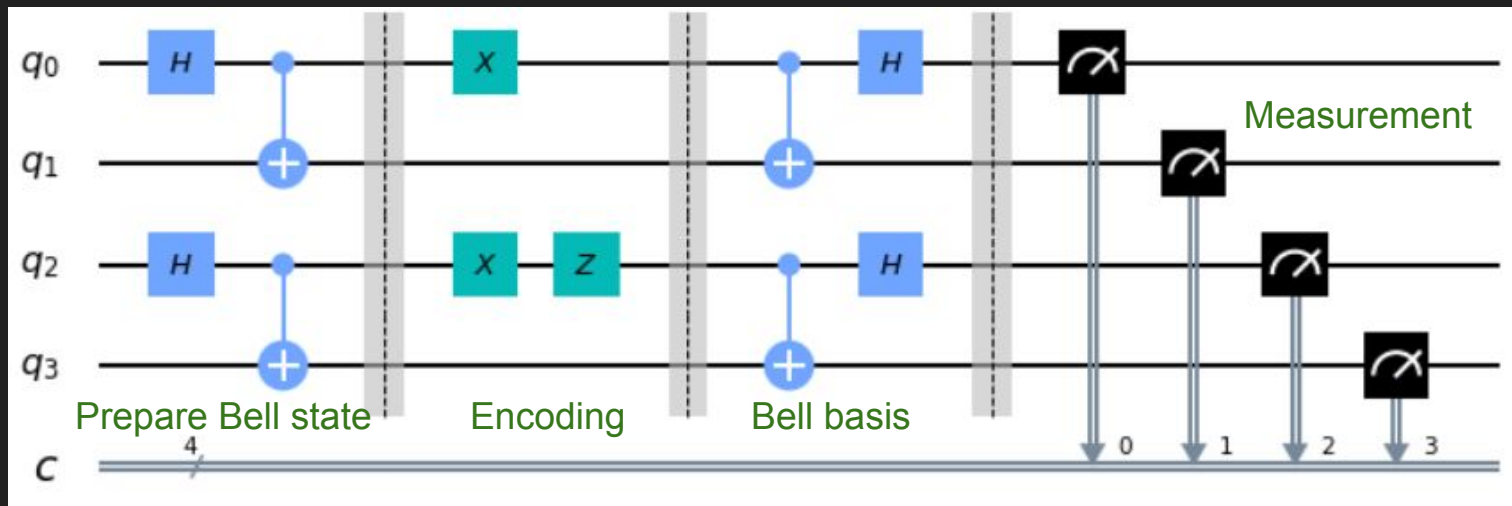
Super Dense Coding using Bell State

- Transmit 2 classical bits of information by sending only one qubit
- Alice and Bob each share one qubit of a Bell pair
- Sender (Alice) performs one of four local operations before sending it to Bob
- By measuring the two particles jointly (in Bell basis), Bob can now reliably learn which operator Alice used and deterministically retrieves the information



Source: Wikipedia

Scheme to encode 4 bits in two Bell pairs



Local operations by Alice to encode 4 bits in 16 distinct states

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
q_0	I	Z	X	ZX	I	Z	X	ZX	I	Z	X	ZX	I	Z	X	ZX
q_2	I	I	I	I	Z	Z	Z	Z	X	X	X	X	ZX	ZX	ZX	ZX

Pre-processing of data

- Reduce resolution of input image
- Convert color into grayscale - default is 8 bit
- Each pixel is converted to a 4 bit number (0 to 15)
- The array of 4-bit numbers is repackaged to an array of 3-bit numbers if GHZ state is used
- Text information is transmitted by each character's ASCII value and repackaged to arrays of 4-bit or 3-bit numbers depending on whether Bell or GHZ state is used
- Based on the value of each element and the selected technique, a set of qubit operations are generated to encode the information



Original



40 X 40 pixels

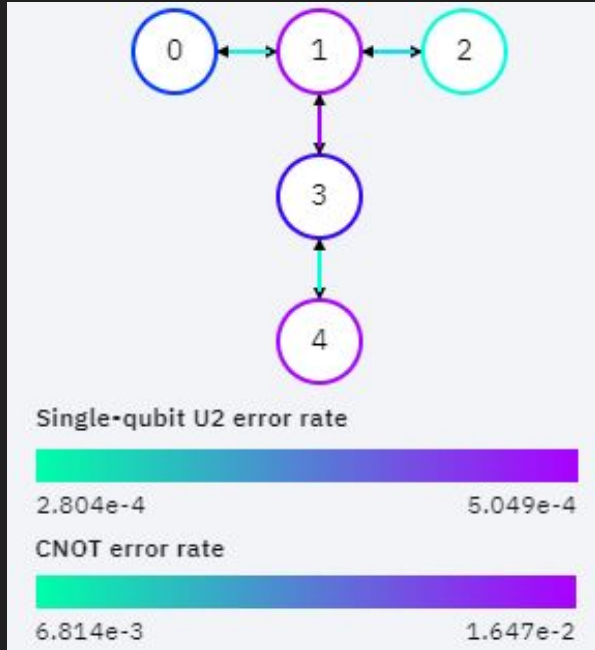


4 bit grayscale



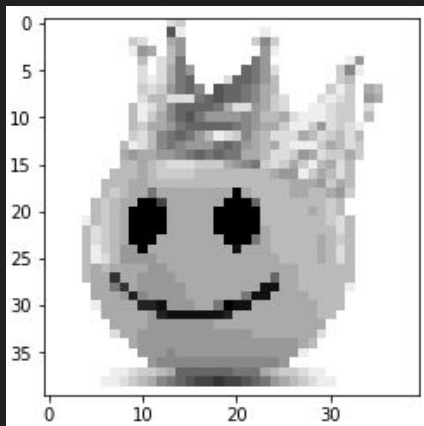
8 bit grayscale

Quantum hardware: “ibmq_ourense”

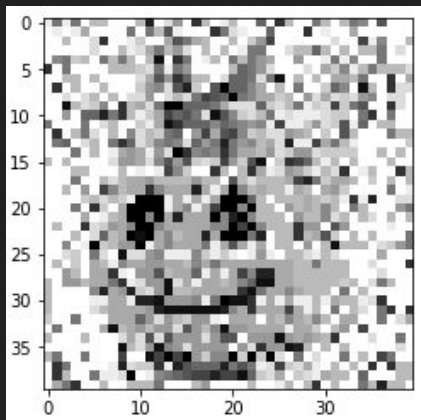


- For Bell state used qubits 1, 2, 3, and 4
- For GHZ states used qubits 0, 1, and 2

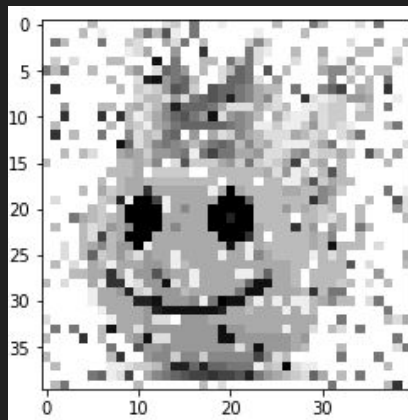
Results of transmission using Bell state



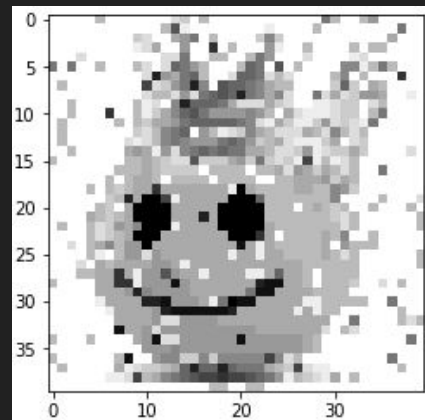
Original image



Typical single run
Success = 55%



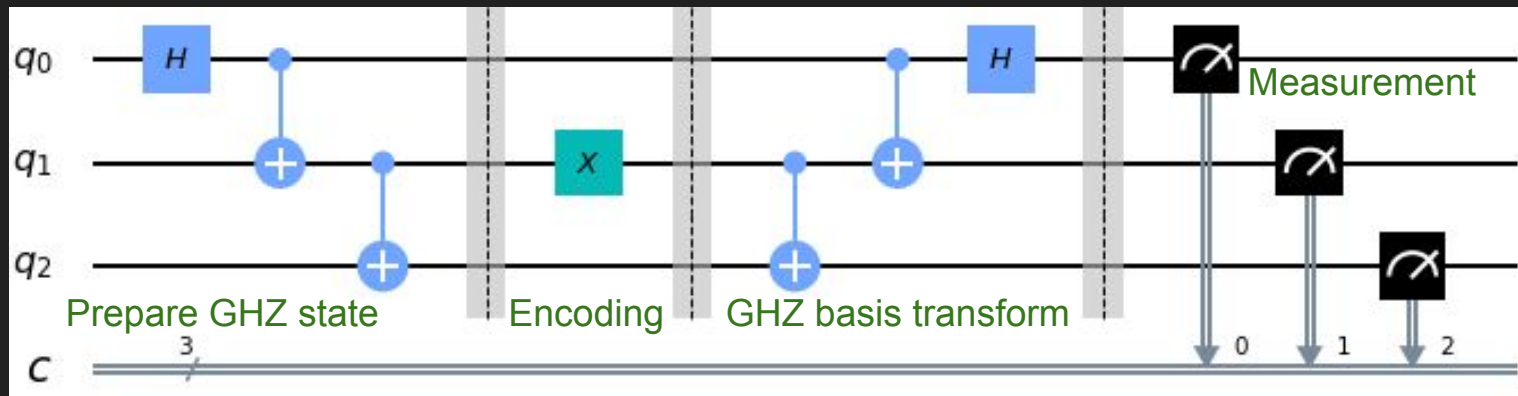
Majority vote (3 runs)
Success = 77%



Majority vote (5 runs)
Success = 86%

Operation	Retrieved message	Success rate
Original	We Love Qiskit Summer Jam 2020.	
Typical single run	we!Lofe 1:smIt0Sum}i6%JiI 3020.	50%
Majority vote (3 runs)	We Love Qhsoit Su}}er JaI 2020.	84%
Majority vote (5 runs)	*e Love Qhskid Summer JaI 2020.	87%

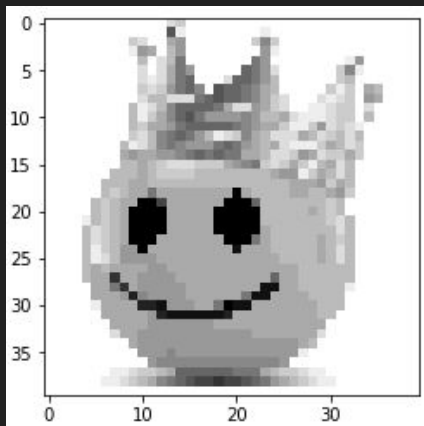
Scheme to encode 3 bits in a GHZ state



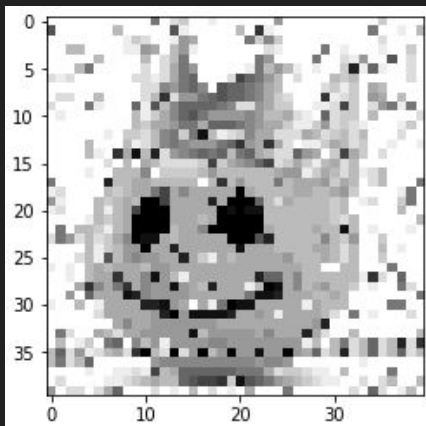
Local operations by Alice to encode 3 bits in 8 distinct states

#	0	1	2	3	4	5	6	7
q0	I	Z	X	XZ	X	XZ	I	Z
q1	I	I	I	I	X	X	X	X

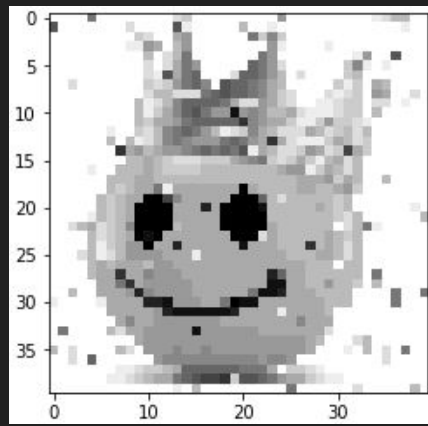
Results of transmission using GHZ state



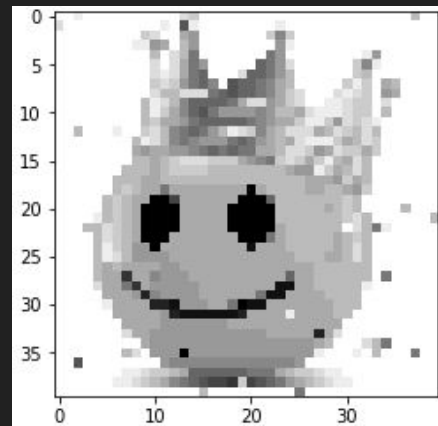
Original image



Typical single run
Success = 76%



Majority vote (3 runs)
Success = 94%



Majority vote (5 runs)
Success = 98%

Operation	Retrieved message	Success rate
Original	We Love Qiskit Summer Jam 2020.	
Typical single run	Ue L/ve Qiskid Aeeeer Jal@220.	67%
Majority vote (3 runs)	We L/Ve Qiskit SumMer Jam 2020.	90%
Majority vote (5 runs)	We Love Qiskit Summer Jam 2020.	100%

Summary

- Demonstrated secure transmission of information using superdense coding
- Two forms of information - grayscale image and text message
- We used two schemes
 - Encoding 4 bits in two **Bell states**
 - Encoding 3 bits in one **GHZ state**
- Transmission with GHZ seemed to perform better (with or without classical error-correction)



THANK YOU